Claims

1. A photonic crystal coupling defect waveguide comprising:

a photonic crystal including photonic crystal elements constituting a periodic structure and, for suppressing propagation of an electromagnetic field including light or a radio wave of a specific wavelength or in a specific frequency range; and

a coupling waveguide including at least two waveguides, each of which includes a line defect that is a plurality of defects which are portions where the photonic crystal elements constituting the periodic structure of the photonic crystal are locally removed as line and forms the waveguide in the photonic crystal, and an input end or an output end for inputting and/or outputting the electromagnetic field and, which are mode-coupled to each other and, in which an electromagnetic field inputted to one of the waveguides causes an electromagnetic field to be propagated to the other waveguide,

wherein

by one of or more than one of (1) effectively changing a medium constant including one of or more than one of a dielectric constant, a refractive index, a conductivity and a magnetic permeability of the photonic crystal, (2) effectively changing size or shape of the photonic crystal elements, and (3) changing a lattice constant indicating a periodic interval of the photonic crystal elements,

(a) band structures of an even mode and an odd mode of the coupling waveguide are shifted with respect to a normalized frequency, or (b) the band structures of the even mode and the odd mode of the coupling waveguide are respectively changed at different degrees;

and by this, a difference in propagation constant between the even mode and the odd mode at a normalized frequency is made large, and a coupling length of a mode-coupled propagating

electromagnetic wave which propagates in the coupling waveguide is made short.

2. The photonic crystal coupling defect waveguide according to claim 1, wherein

a material of a part of the photonic crystal including a part of or whole of the coupling waveguide is different from a material of another part.

3. The photonic crystal coupling defect waveguide according to claim 1, wherein

in a part of the photonic crystal including a part of or whole of the coupling waveguide, one of or more than one of a lattice constant, size of the photonic crystal elements, and shape of the photonic crystal elements are different from those of another part.

4. The photonic crystal coupling defect waveguide according to claim 3, wherein

in the part of the photonic crystal including the part of or the whole of the coupling waveguide, the shape of the photonic crystal elements are not changed with respect to the another part, and the lattice constant and the size of the photonic crystal elements are changed similarly and at a same rate as compared with the another part.

5. The photonic crystal coupling defect waveguide according to claim 1, wherein

the photonic crystal is a two-dimensional photonic crystal including the photonic crystal elements in a plane direction of a slab, and

in a part of the two-dimensional photonic crystal including a part of or whole of the coupling waveguide, a thickness of the

slab is different from that of another part.

6. The photonic crystal coupling defect waveguide according to claim 1, wherein

with respect to the photonic crystal elements adjacent to the coupling waveguide and/or the photonic crystal elements in the vicinity of the coupling waveguide or between the waveguides, one of or more than one of a lattice constant, size of the photonic crystal elements, and shape of the photonic crystal elements are different locally from those of another part.

7. The photonic crystal coupling defect waveguide according to claim 1, wherein

to the photonic crystal elements adjacent to the coupling waveguide and/or the photonic crystal elements in the vicinity of the coupling waveguide or between the waveguides, elements that size and/or shape are/is different from those of the photonic crystal elements are added.

8. The photonic crystal coupling defect waveguide according to claim 3, 4 or 6, wherein

positions of the photonic crystal elements adjacent to the line defect of the coupling waveguide or the waveguide are shifted so that the width of the line defect or the waveguide is not changed or is hardly changed, and one of or more than one of the lattice constant, the size of the photonic crystal elements, and the shape of the photonic crystal elements adjacent to or in the vicinity of the line defect or the waveguide or between the waveguides are different from those of another part.

9. The photonic crystal coupling defect waveguide according to any one of claims 1 to 8, wherein

one of or more than one of the waveguides constituting the coupling waveguide include discontinuous defect lines, and perform as a delay line.

10. The photonic crystal coupling defect waveguide according to claim 1, further comprising

a region in which one of or more than one of an effective dielectric constant, a conductivity and a magnetic permeability of the photonic crystal are made variable by a control signal of an electromagnetic field including light or a radio wave and/or an electric field and/or a magnetic field applied from outside,

wherein a propagation constant of the electromagnetic wave and/or a degree of coupling can be controlled.

11. The photonic crystal coupling defect waveguide according to claim 1, further comprising

a nonlinear medium region realized by formation of quantum dots or doping of ions in a periphery of the defect of the photonic crystal or in a part of or whole of an inside,

wherein one of or more than one of an effective dielectric constant, a conductivity and a magnetic permeability of the medium is made variable by applying an electromagnetic field including light or a radio wave and/or an electric field and/or a magnetic field to the nonlinear medium region.

12. The photonic crystal coupling defect waveguide according to any one of claims 1 to 11, wherein

the photonic crystal has a two-dimensional photonic crystal slab structure, and

the coupling waveguide is realized by two single line defects arranged to be close to each other or to be spaced from each other by a specified distance, and, to be in parallel to each other.

13. The photonic crystal coupling defect waveguide according to any one of claims 1 to 12, wherein

the input end and/or the output end is provided with an input port and/or an output port that includes one of a wave guide tube, a coaxial cable, an optical fiber, a high refractive index difference waveguide and a photonic crystal defect waveguide and is for inputting and/or outputting an electromagnetic wave, and coupling to an external system is enabled.

14. The photonic crystal coupling defect waveguide according to claim 1, wherein

by (1) substantially changing a medium constant including one of or more than one of a dielectric constant, a refractive index, a conductivity and a magnetic permeability of the photonic crystal,

(a) band structures of an even mode and an odd mode of the coupling waveguide are shifted with respect to a normalized frequency.

15. The photonic crystal coupling defect waveguide according to claim 1, wherein

by (2) substantially changing sizes or shapes of the photonic crystal elements,

(a) band structures of an even mode and an odd mode of the coupling waveguide are shifted with respect to a normalized frequency.

16. The photonic crystal coupling defect waveguide according to claim 1, wherein

by (3) changing a lattice constant indicating a periodic interval of the photonic crystal elements,

(a) band structures of an even mode and an odd mode of the

coupling waveguide are shifted with respect to a normalized frequency.

17. The photonic crystal coupling defect waveguide according to claim 1, wherein

by (1) substantially changing a medium constant including one of or more than one of a dielectric constant, a refractive index, a conductivity and a magnetic permeability of the photonic crystal,

(b) the band structures of the even mode and the odd mode of the coupling waveguide are respectively changed at different degrees.

18. The photonic crystal coupling defect waveguide according to claim 1, wherein

by (2) substantially changing sizes or shapes of the photonic crystal elements,

(b) the band structures of the even mode and the odd mode of the coupling waveguide are respectively changed at different degrees.

19. The photonic crystal coupling defect waveguide according to claim 1, wherein

by (3) changing a lattice constant indicating a periodic interval of the photonic crystal elements,

(b) the band structures of the even mode and the odd mode of the coupling waveguide are respectively changed at different degrees.

20. The photonic crystal coupling defect waveguide according to claim 1, wherein

a material of a part in a slab place locally varies, and/or a material in a thickness direction of the slab partially varies.

21. The photonic crystal coupling defect waveguide according to claim 1, wherein

portions of different materials or different medium constants are connected to each other through a portion where a material or a medium constant is gradually changed or continuously changed.

22. The photonic crystal coupling defect waveguide according to claim 1, wherein

portions having different slab thicknesses are connected to each other through a portion where a slab thickness is gradually changed or continuously changed.

23. The photonic crystal coupling defect waveguide according to claim 1, wherein the size of the photonic crystal elements and the lattice constant are changed at a same rate.

24. The photonic crystal coupling defect waveguide according to claim 1, wherein

by adding to a part of the photonic crystal including a part of or whole of the coupling waveguide, an element of a size and/or a shape which are/is different from the photonic crystal elements, and the part is made different from another part.

25. The photonic crystal coupling defect waveguide according to claim 3, 4 or 6, wherein

in the photonic crystal adjacent to or in the vicinity of the line defect of the coupling waveguide or the waveguide or between the waveguides, one of or more than one of the lattice constant, the size of the photonic crystal elements, and the shape of the photonic crystal elements are made different from those of another

part, and a width of the line defect or the waveguide is locally changed.

26. The photonic crystal coupling defect waveguide according to claim 3, 4 or 6, wherein

in the photonic crystal adjacent to or in the vicinity of the line defect of the coupling waveguide or the waveguide or between the waveguides, one of or more than one of the lattice constant, the size of the photonic crystal elements, and the shape of the photonic crystal elements are made different from those of another part, and positions of the photonic crystal elements are locally shifted so that a width of the line defect or the waveguide is not changed or is hardly changed.

27. The photonic crystal coupling defect waveguide according to claim 5, wherein a thickness of the slab is changed step-wise or stair-wise.

28. The photonic crystal coupling defect waveguide according to claim 1, further comprising

a region where one of or more than one of an effective dielectric constant, a conductivity and a magnetic permeability of the photonic crystal is made variable by heat applied from outside,

wherein a propagation constant of an electromagnetic wave and/or a degree of coupling can be controlled.

29. A photonic crystal device comprising:

a photonic crystal coupling defect waveguide according to any one of claims 1 to 28,

wherein when an electromagnetic field is inputted to one waveguide of the coupling waveguide, coupling occurs between

waveguides constituting the coupling waveguide, the electromagnetic field is propagated to the other waveguide, and the electromagnetic field is outputted from one of or more than one of the waveguides, and the photonic crystal device performs as one of a directional coupler in electromagnetic wave transmission, a divider/branching unit, a coupler, a multiplexing combiner, a demultiplexer, a resonator, a filter and a switch.